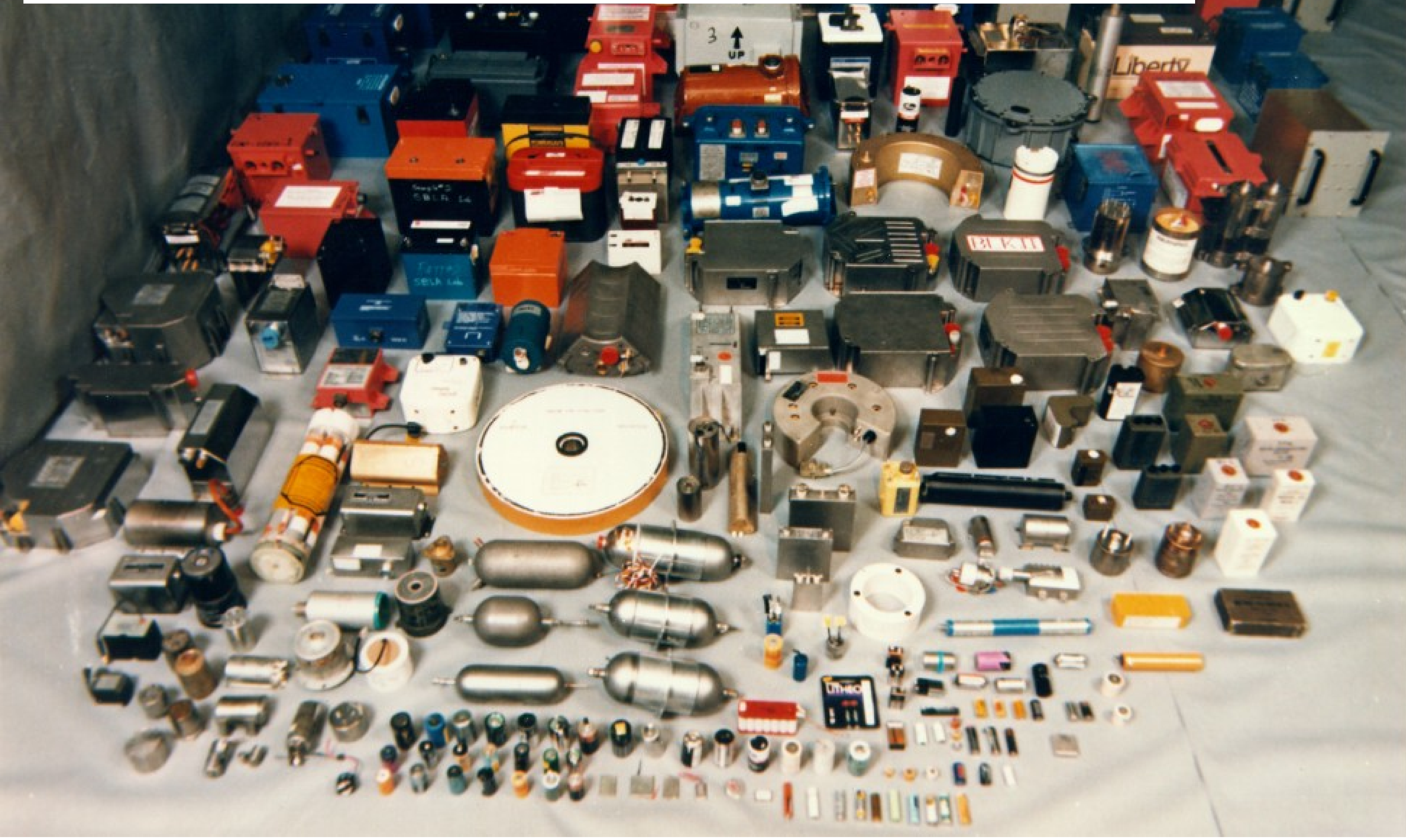
NAVSEA WARFARE CENTERS

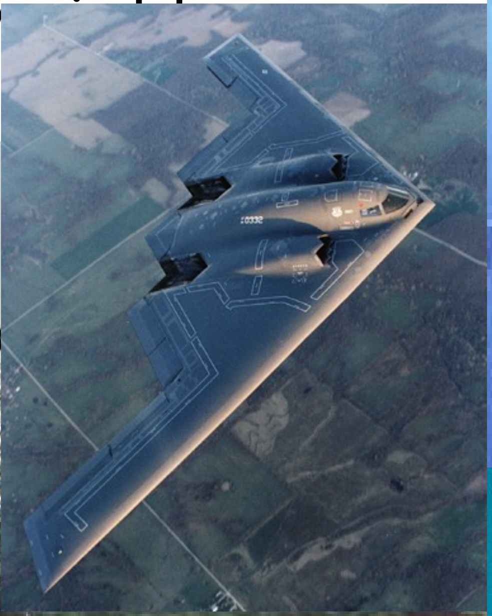
CRANE

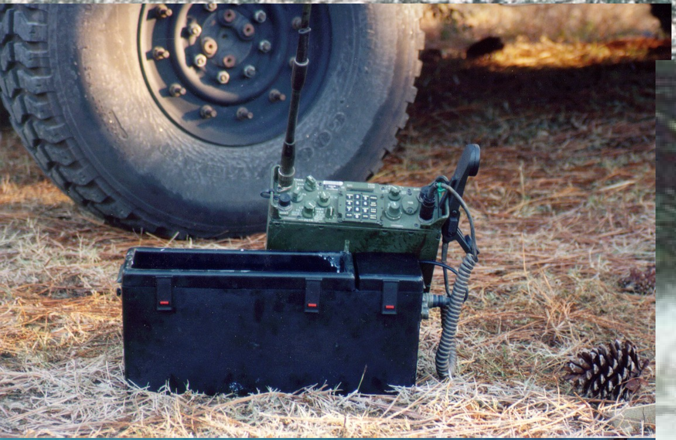
Lead-acid Battery Safety

Batteries are produced in all shapes and sizes. Each has specific volumetric and power capabilities.



To meet the mission electrical, environmental, size and w
requirements.





LEAD-ACID BATTERY TRAINING

Battery Terminology

Charge: The conversion of electrical into chemical energy.

Cycle : One complete discharge and charge or vice-versa.

Capacity: The battery's ability to provide a sustained current for a given duration of time. Units: Ampere-hours (Ah).

Power: Time rate of doing work.

Power (Watts) = E(Volts) x I(Amps)

LEAD-ACID BATTERY TRAINING

Battery Terminology

Energy Density: The energy that can be achieved by a battery per unit volume or mass. Usually in units of Watt-hours/liter or Watt-hours/kilogram.

Self Discharge: The process in which a battery discharges with out an external load due to internal chemical reactions.

Battery Terminology

Charge Voltage: Voltage which a cell reads at full charge. A Lead-Acid cell will read approximately 2.375 V at full charge.

Open Circuit Voltage (OCV): Voltage which a cell exhibits as a function of its state-of-charge. The OCV of a fully charged lead-acid cell is 2.15 V.

LEAD-ACID BATTERY TRAINING

Lead-Acid Battery Chemical Reaction

The lead-acid battery consists of a **lead (Pb)** anode and a **lead dioxide (PbO_2)** cathode with a **sulfuric acid (H_2SO_4)** electrolyte.

The half-cell reactions from the table of standard electrode potentials are as follows:

Cathode reaction: $\mathbf{PbO_2(s) + SO_4^{2-}(aq) + 4H^{-}(aq) + 2e^{-} \rightarrow PbSO_4(s) + 2\,H_2O(l)}$ (1.69 V)

Anode reaction: $\mathbf{Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^{-}}$ (-0.36 V)

LEAD-ACID BATTERY TRAINING

Lead-Acid Battery Chemical Reaction

The overall reaction is:

$$\mathbf{PbO_2(s) + SO_4^{2-}(aq) + 4H^{-}(aq) + 2e^{-} + Pb(s) + SO_4^{2-}(aq)}$$

$$\mathbf{\rightarrow PbSO_4(s) + 2\ H_2O(l) + PbSO_4(s) + 2e^{-}}$$

Rearranging terms:

$$\mathbf{PbO_2(s) + Pb(s) + 4H^{-}(aq) + SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2\ H_2O(l)}$$

Simplifying notation this becomes:

$$\mathbf{PbO_2 + Pb + 2H_2SO_4 \rightarrow 2PbSO_4 + 2\ H_2O}$$

Lead-Acid Battery Chemical Reaction

On **overcharge**, **electrolysis** takes place, with oxygen evolution at the positive electrode and hydrogen evolution at the negative electrode.

The chemical reaction on overcharge is:

$$\mathbf{2H_2O \rightleftarrows 4H^+ + 4e^- + O_2}$$

Charge $\longrightarrow$ $\longleftarrow$ Discharge

Valve Regulated Lead-Acid Batteries

Overview:

When a traditional flooded lead-acid cell is charged, gas is released. This occurs when water, through the process of electrolysis, decomposes into its forming elements. To maintain the chemical balance in the cell, the lost water must be replaced periodically.

In valve-regulated batteries, the created oxygen gases are recombined during the charge phase, through the cycle of oxygen recombination, thereby producing water as described in the following cycle:

Valve Regulated Lead-Acid Batteries

The Chemistry

At the positive plates, oxygen is generated by water electrolysis:

$$H_2O \Longrightarrow 1/2\ O_2 + 2H^+ + 2e^-$$

and is diffused through the separators to the negative plates.

At the negative plates, the oxygen combines with a part of the lead contained in these plates producing lead oxide:

$$Pb + 1/2\ O_2 \Longrightarrow PbO$$

Valve Regulated Lead-Acid Batteries

The Chemistry (cont.):

The lead oxide combines with the sulphuric acid of the electrolyte, forming lead sulphate and water:

$$PbO + H_2SO_4 ==> PbSO_4 + H_2O$$

Water is therefore regenerated on the positive plates, while lead sulphate is formed from the partially discharged negative plates.

The charge process recharges the partially discharged negative plates, thereby closing the cycle.

$$PbSO_4 + 2H^+ + 2e^- ==> Pb + H_2SO_4$$

Valve Regulated Lead-Acid Batteries

The Chemistry (cont.):

The recombination cycle, as described above, is therefore theoretically complete. The constituent parts of water and sulfuric acid in the electrolyte, as well as the amount of lead of the negative plates, reappear at the end of the process in their original state, without having modified the charge conditions of the plates.

Valve Regulated Lead-Acid Batteries

Necessary conditions

To facilitate the diffusion of oxygen, highly uniform and porous separators are used. Furthermore, to avoid saturating the available porosity of these same separators, the quantity of electrolyte must be carefully measured, thereby ensuring that the electrolyte is completely contained inside the plates and the separators, **leaving no free electrolyte inside the battery container.**

Valve Regulated Lead-Acid Batteries

Necessary conditions (cont.)

To prevent oxidation of the negative lead plates, the electrical elements must be in fully closed containers. At the same time, it is necessary to allow the venting of any over pressurization of gases which may be generated within the container during overcharge conditions.

Every cell is therefore equipped with a one-way valve. This valve allows excess gases to be vented when required, but does not permit outside air to enter. The presence of these one-way valves gives rise to the term **"valve-regulated"** for this type battery.

LEAD-ACID BATTERY TRAINING

Environmental Considerations

Batteries must be designed to provide the required performance and operating life under the expected environmental conditions.

Battery performance varies directly with temperature. Operation at high temperature may cause excessive loss of electrolyte and shortened battery life.

Battery life may also be reduced when subjected to excessive vibration (negated by use of shock mounts), mechanical shock or corrosive environments.

LEAD-ACID BATTERY TRAINING

Acid

Sulfuric acid (H_2SO_4) solution is the electrolyte of the lead-acid cell. This solution takes an active part in the chemical reactions that produce energy from the cell. By changing the density or specific gravity of the acid solution, performance factors such as capacity, maintenance, and life can be affected.

In most cell designs, the acid is available as a free liquid in which the plates are immersed. **In cells of valve-regulated aircraft batteries, the acid is immobilized and absorbed completely in the separator structure.**

The relationship between specific gravity, battery capacity, maintenance, and life are shown below.

ACID ELECTROLYTE EFFECT ON BATTERY PERFORMANCE

SPECIFIC GRAVITY	CAPACITY	MAINTENANCE	LIFE
Higher	Increase	Increase	Decrease
Lower	Decrease	Decrease	Increase

Vents

Cells must be vented to avoid pressure buildup that could result (at very high pressures) in cracking of the container and spillage of electrolyte. Even while standing on open circuit, gases are released due to local action.

Venting is usually achieved through a baffled plug fitted into the cover. In some designs, this plug is replaced by a flame arrester vent, which does not allow a flame to penetrate to the inside of the cell where there could be an explosive concentration of hydrogen. Vents may be individually placed in each cell or grouped into one piece for easy installation and removal.

Most cells are constantly vented to the atmosphere. However, valve-regulated cell designs incorporate a pressure relief valve. These do not vent unless internal pressure has exceeded the design pressure of the valve. When the pressure bleeds the valve reseals or closes.

Design Factors For Safety

Safety of a cell or battery can be enhanced by the choice of design factors as shown below.

DESIGN FACTORS FOR SAFETY

COMPONENT	DESIGN FACTOR	IMPACT
Internal Connections	Bond Design	Internal Sparks
Seals	Container/Cover Seal Design	Grounding, Electrolyte Leakage
Vents	•Baffling •Flash Arresters	•Grounding •Internal Gas Ignition
Container/Cover	Material Choice	•Flame Retardance •Impact Resistance
Connectors	•Insulation •Sizing	•Electric Shock •Burns

LEAD-ACID BATTERY TRAINING

Advantages

Advantages of Lead-Acid Systems:

- **Low cost**
- Large quantities, sizes, and designs
- Highest aqueous system cell voltage (2.15 Vdc)
- **Maintenance free designs available as starved electrolyte**
- Good high and low temperature performance, -29 to 66C (-20 to 150F)

LEAD-ACID BATTERY TRAINING

Disadvantages

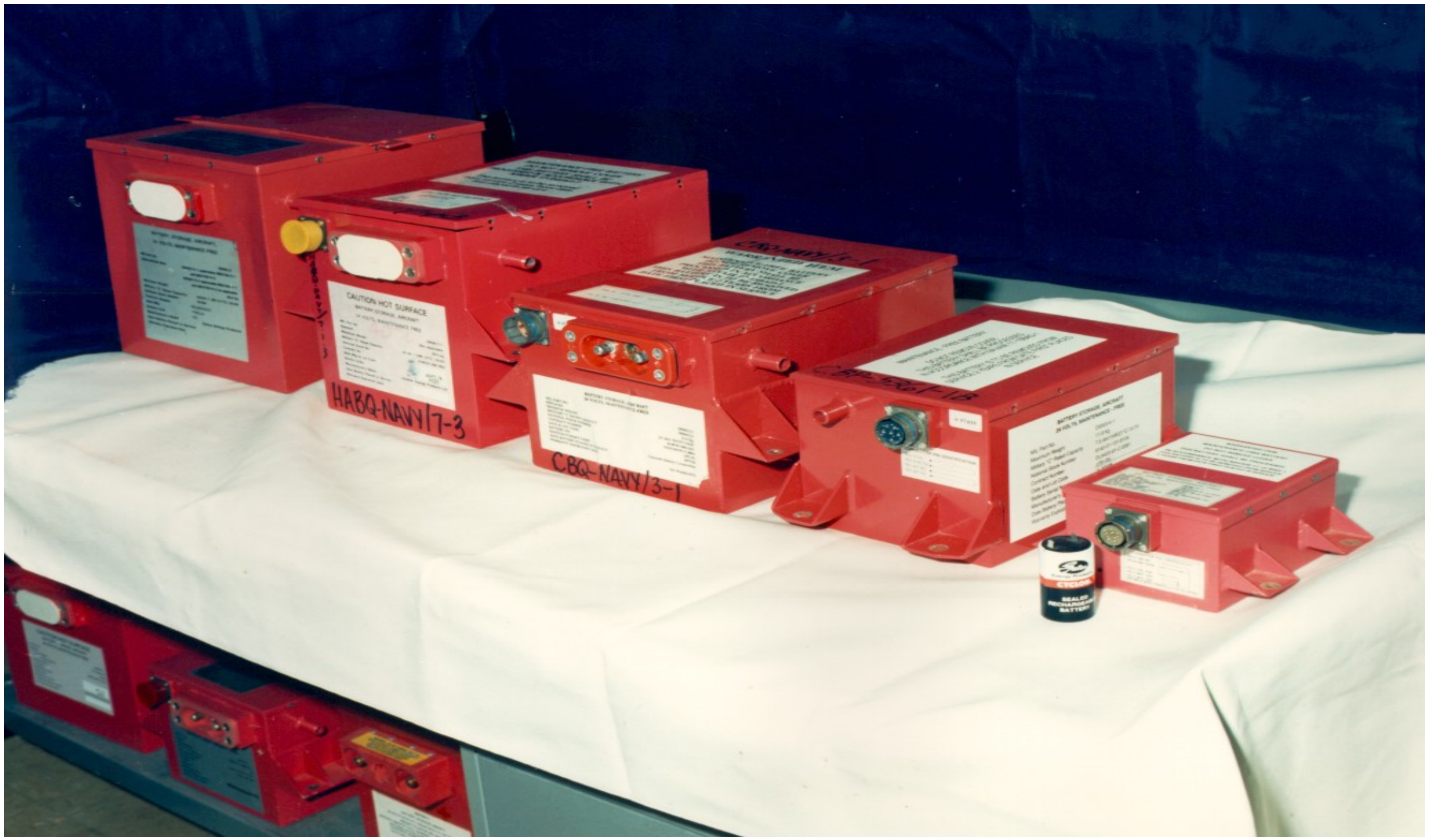
Disadvantages of Lead-Acid Systems:

- Relatively low cycle life under large Depth of Discharg
- Limited energy density (70-80 Wh/l, 30-40 Wh/kg) tra
  to larger volume and weight requirements
- **Long term storage in discharged state can cause**
  damage via electrode sulfation.
- **Never leave a battery discharged any longer tha**
  Recharge immediately!!!!!!!!!
- Hydrogen evolution during recharge may create expl
  hazard
- Difficult to miniaturize

LEAD-ACID BATTERY TRAINING

Examples

NAVSEA CRANE



Lead-Acid Aircraft Batteries

LEAD-ACID BATTERY TRAINING

Lab Safety - “Do”s

- Keep battery terminals covered when possibl
- Keep batteries away from high heat and use e
caution when soldering or heat shrinking
- Always work on a non-conductive surface
- Be aware of voltages (35+ Vdc): Use the one h

LEAD-ACID BATTERY TRAINING

Lab Safety - “Do’s”

- **Have Material Safety Data Sheets (MSDS’s) available**

- **Remove exposed jewelry i.e.., watches, rings, etc.**

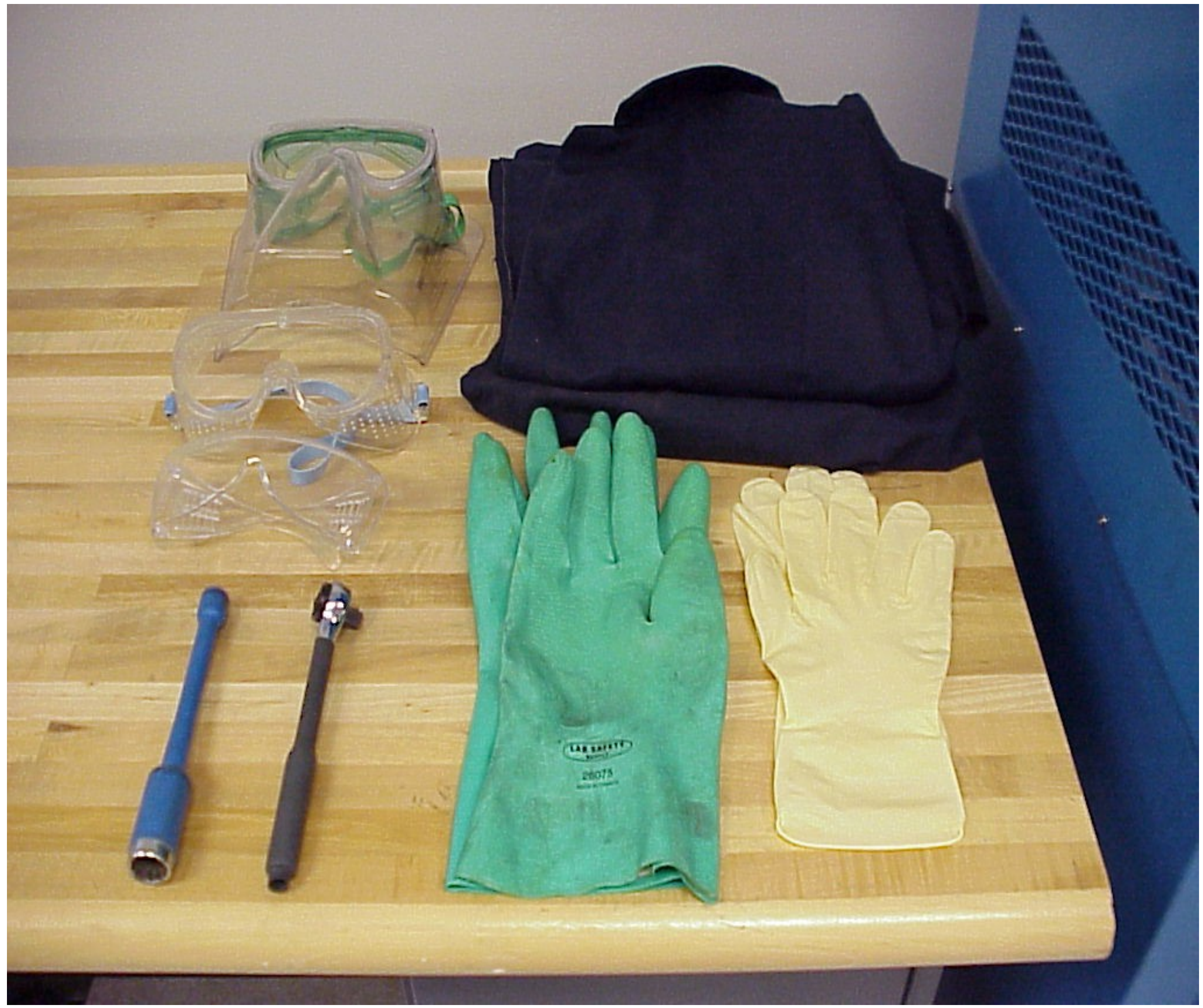
- **Flush unknown liquids with large amounts of water**

- **Be aware of carcinogenic heavy metals i.e., Cr, Pb, Cd,**
  and Hg (chromium, lead, cadmium, and mercury)

LEAD-ACID BATTERY TRAINING

Safety Equipment in the Lab

Eye Protection
Chemical
Gloves
Plastic Bags
Paper Towels
Insulated Work
Surface
Good Lighting
Proper
Equipment



LEAD-ACID BATTERY TRAINING

Lab Safety – Sulfuric Acid Electrolyte

- Clean spilled electrolyte immediately
- Use baking soda as a neutralizing solution
- Use large amounts of water to remove electrolyte from skin.
- If electrolyte gets into eyes, flush thoroughly and seek help.
- If ingested, take large quantities of water and a weak alkaline solution such as sodium bicarbonate. Seek medical attention immediately.
- Use your shop safety equipment at all times